PART TWO

PM_{10} Monitoring

Chapter 7

Part Two - PM_{10} Monitoring

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1.0 Introduction

On July 1, 1987, the U.S. Environmental Protection Agency (EPA) promulgated a new size specific air quality standard for ambient particulate matter. This new primary standard, designated as PM_{10}, applies to particulate matter in the atmosphere that has an aerodynamic diameter of 10 micrometers or less (one micrometer or µm equals 10^{-6} meter). The PM_{10} primary standard replaced the original standard for Total Suspended Particulates (TSP).

In conjunction with the new standard, the EPA promulgated a new federal reference method to measure PM concentrations (FRM). A PM_{10} sampler draws a high volume of ambient air at a constant flow rate through a size selective inlet. Particles in the PM_{10} size range are then collected on an 8" x 10" quartz filter over a 24-hour sampling period. Each filter is weighed before and after sampling to determine the net weight gain or mass of the collected PM_{10} sample. The reference method for PM_{10} sampling is given in the *Code of Federal Regulations,* 40 CFR Part 50, Appendix L, CFR Part 50, Appendix M.

The total volume of air sampled is determined from the measured volumetric flow rate and the total sampling time. The concentration of PM_{10} is computed as the mass gain of the filter divided by the volume of air sampled and the measurement is reported as micrograms per standard cubic meter of air (µg/m^3).

The differences between mass flow rate, standard flow rate, and actual flow rate can be somewhat confusing. Also when discussing "flow rate", sometimes the "rate" (per unit of time) is dropped and only the term "flow" is used. Definitions of the following terms maybe helpful to the reader:

Mass Flow Rate - A certain number of molecules (mass) of air passing a point over a unit of time (i.e., minute). The number of molecules remains the same even if the surrounding ambient temperature and barometric pressure change.

Actual Flow Rate - A certain volume of air passing a point over a unit of time. The volume increases or decreases if the temperature and/or pressure changes.

To illustrate the difference between the two flow rates, apply a small amount of heat to a balloon and it expands (volume increases), but the mass of air (number of molecules) remains the same.

Standard Flow Rate - A certain volume of air passing a point over a unit of time. Regardless of the ambient temperature and barometric pressure, the volume is "standardized or referenced" to a standard temperature and pressure.

Standard Reference Conditions (@SRC) are defined as a temperature of 25 ^{o}C (298 K) and a barometric pressure of 760 mmHg (1 atmosphere).

1.1 PM_{10} Sampler Designs

Two common types of samplers that meet designation requirements are the high volume (hi-vol) PM_{10} and dichotomous samplers. Only high volume PM_{10} samplers are discussed in this chapter. Information on dichotomous samplers is found in the USEPA Quality Assurance Guidance Document 2.1.0.

High volume PM_{10} samplers consist of two basic components: a size selective inlet that allows particles 10 µm and less in diameter to pass through to the sample filter, and a flow-control system capable of maintaining a constant flow rate within the design specifications of that sampler inlet. Both systems use an electric blower-type motor to pull the high volume of air through the system.

There are two basic designs of sample inlets. One design uses impaction method of size discrimination and the second uses the cyclonic method of size discrimination. Both have similar flow rate requirements. There are also two common types of flow control systems, mass flow controlled (MFC) and volumetric flow controlled (VFC). These flow control systems differ significantly in calibration and operating procedures, but they can be used with either type of sample inlet.

Described below are the basic operating principles of the two types of sample inlets and flow controlling systems.

- **Impaction Inlet** (Figure 1) - Ambient air is drawn into the inlet and evacuated from a buffer chamber through nine acceleration nozzles and into the first impaction chamber, where initial particle size separation occurs. The air is then accelerated through 16 additional jets into a second impaction chamber. These jets have critical diameters that provide the necessary changes in velocity to effect correct particle size fractionation within the impaction chambers. The airflow finally exits the inlet through nine vent tubes and onto the sample filter. Because air velocities are critical to maintain the correct particle size cut point, maintaining the correct flow rate through the inlet is essential. This flow rate is specified by the manufacturer.

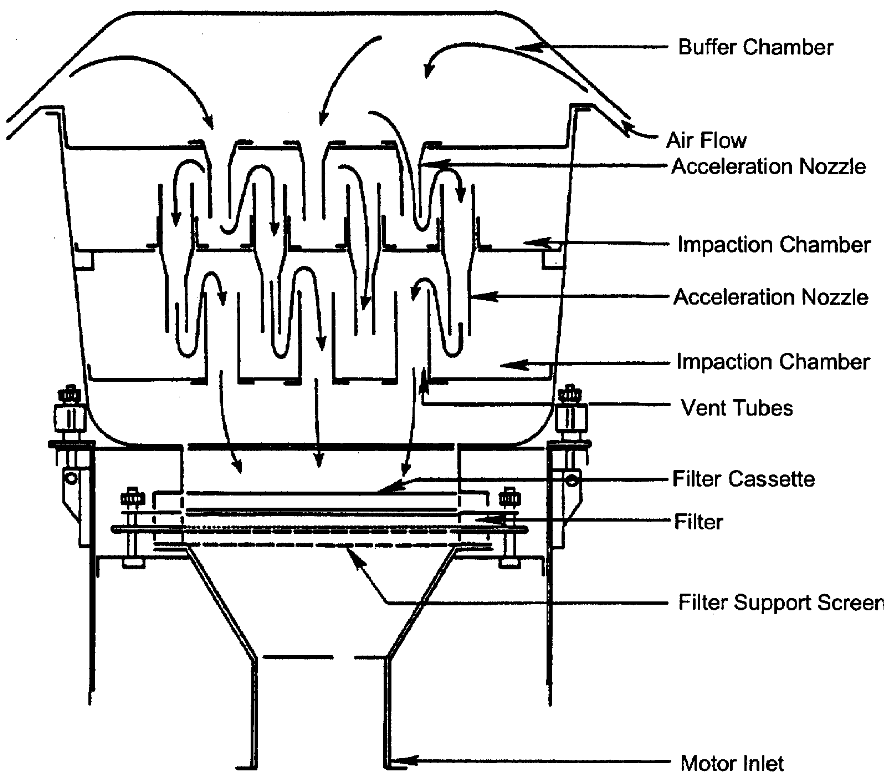

Figure 1
Impaction Inlet

- **Cyclonic Inlet** (Figure 2) - An angular velocity component is imparted to the air stream and the particles contained in it by a series of evenly spaced vanes. Large particle removal occurs in an inner collection tube. This tube incorporates an oil-coated surface to eliminate particle bounce. The sample flow of remaining particles then enters an intermediate tube, where the trajectory is altered to an upward direction. An additional turn is then made to alter the flow to a downward trajectory allowing the remaining particulate to deposit on the filter. As with the impaction inlet, maintaining correct design flow rate is essential for correct particle sizing.

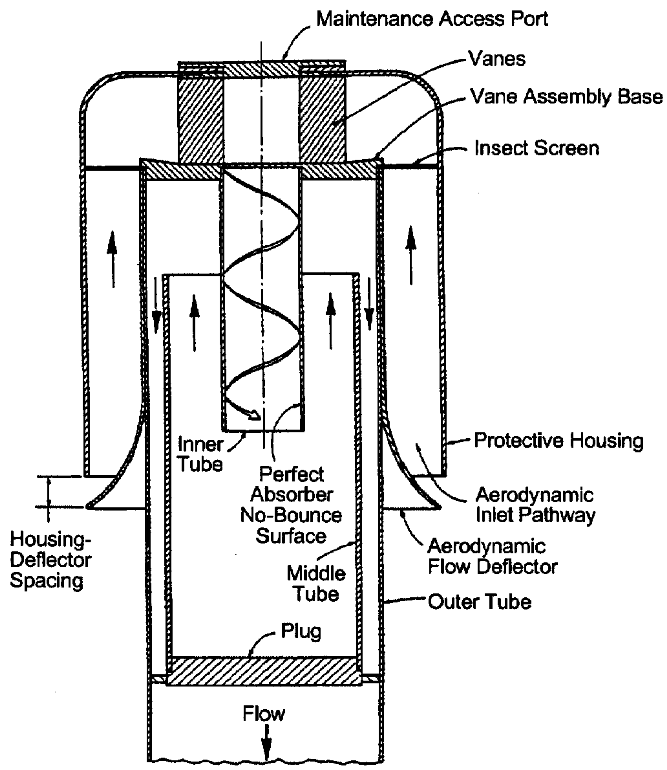

Figure 2
Cyclonic Inlet

- **Mass Flow Control (MFC) System** - Air is drawn through a filter into an intake of a blower and exits the sampler through holes in the base of the blower. Flow rate is controlled by an electronic mass flow controller which uses a flow sensor installed below the filter holder to monitor the mass flow rate and to control the speed of the motor accordingly. The controlled flow rate is adjusted with a potentiometer located inside the electronics box.

- **Volumetric Flow Control (VFC) System** - This system maintains a constant flow rate through the inlet rather than a constant mass flow rate as in the MFC. A venturi-type device is operated such that the air attains sonic velocity in the throat of the device. The flow rate is unaffected by downstream conditions such as motor speed or exit pressure and is a function for the inlet pressure and temperature. Volumetric flow is controlled without any moving parts or electronic components. In this type of flow control system, the flow rate cannot be adjusted.

Photo 1 Mass Flow Controller

2.0 Facility Requirements

Facility requirements for PM_{10} sampling include a central laboratory that includes a filter conditioning and weighing area, a calibration and maintenance area, and individual field sampling stations.

2.1 Filter Conditioning and Weighing Area

Accuracy of a PM_{10} sampling program is largely dependent on the analytical laboratory staff's attention to detail and balance technique. The filter conditioning room should be large enough to accommodate filter processing, equilibration, weighing operations, as well as filter and record storage. The room should be equipped with the necessary air conditioning equipment to maintain an air temperature between 15 °C and 30 °C (constant within ±3 °C) and relative humidity less than 50 percent (constant within ±5%). In addition, certified relative humidity and temperature measurement instruments must be maintained.

2.2 Calibration and Maintenance Area

A sufficiently large area should be designated as the calibration and maintenance test area. It should be equipped with the tools required for routine sampler maintenance, such as brush or motor replacement, orifice certifications, and ancillary equipment maintenance and repair.

2.3 Individual Sampling Stations

All PM_{10} sampling locations must meet the guidelines set forth in 40 CFR Part 50 Appendix L, and Part 58 Appendix D as well as the siting guidelines outlined in Chapter 1, Section 4.0 of this manual. The following factors should also be considered when selecting a monitoring site:

- Samplers should be situated where the operator can access safely regardless of weather conditions. Considerations should also be given that routine operations such as calibration, sampler pickup/setup, flow check, and audit involve transporting equipment and supplies to and from the sampler location.

- Availability of adequate electricity to power sampler(s).

- Security of monitoring personnel and equipment. The security of personnel and the sampler itself depends largely on location. Rooftop sites with locked access and ground level sites with fenced compounds should be utilized whenever possible.

2.4 Ancillary Equipment

Listed below are equipment and supplies required for proper operation of a PM_{10} monitoring network. Detailed specifications for all items are found in the reference method described in 40 CFR Part 50, Appendix L.

Sampling Equipment

- shelter
- size selective inlet head
- flow controller
- blower motor
- elapsed time meter (ETM)
- clock (ON/OFF)
- quartz filters

Audit/Calibration Equipment

- barometer
- manometer
- thermometer
- positive-displacement meter (Roots Meter)
- flow rate transfer standard (Hansen orifice)

Laboratory Equipment

- Filter transfer cards/envelopes
- Relative humidity indicator
- Logbooks/laboratory and maintenance
- Analytical balance
- ANSI/ASTM Class 1, 1.1 or 2 mass reference standard weights

Photo 2 PM_{10} Sampler Components

3.0 Filter Preparation and Analysis

40 CFR Part 50, Appendix L and M outlines the acceptance criteria for filters used in PM_{10} monitoring.

Quartz filter material is brittle and may be easily broken. Care should be taken at all times to avoid damage or contamination.

A unique filter identification number is assigned to each filter by the manufacturer. If filters are to be mailed to a laboratory for analysis, field personnel should be equipped with reinforced envelopes and manila folders for the protection of the exposed filters.

3.1 Filter Inspection

All filters must be inspected for defects before use. An effective filter inspection method is with a light-box. A light-box uses a low wattage light bulb to illuminate a clear or translucent surface. Laying an 8” x 10” quartz filter on this lighted surface aides in the inspection process. Defective filters should not be used for sampling.

Some common defects are:

- pinholes
- loose material
- discoloration
- non-uniform appearance

3.2 Filter Conditioning/Equilibration

Filters must be equilibrated in a conditioning environment for at least 24 hours before initial or tare weighing. The relative humidity of the room should be kept in the range of 20 to 45 percent with a variability of not more than ±5 percent. The temperature must be held in the range of 15 °C to 30 °C with a variability of not more than ±3 °C. The conditions must be verified and recorded on equilibration days to insure compliance with this guideline. Any system malfunctions (heating, air conditioning, etc.), discrepancies, and maintenance activities should be recorded in a laboratory logbook.

3.3 Pre Sampling Filter Weighing Procedures

Filters must be weighed on an analytical balance with a minimum resolution of 0.1 mg and a precision of 0.5 mg. The balance must be calibrated at least annually and maintained according to manufacturer's recommendations. For each lot of filters to be weighed:

Zero the balance and perform a QC check using working mass reference standards. These standard weights should be between 1 and 5 g. If the actual measured value differs by more than ±0.5 mg, delay the filter weighing until the problem has been identified and corrected.

1. If filters are equilibrated in a desiccation chamber rather than in an environmentally controlled room, filters must be weighed within 30 seconds from removal from the chamber.
2. Weigh each filter and record the filter number, tare weight and analyst's initials in logbook or database.
3. After every 5 to 10 weights the laboratory analyst must check the balance zero. Balance calibration should be checked (mass reference weights) after 15 filters, unless documentation indicates the balance is stable over longer periods.
4. On each day of weighing 5 to 7 filters must be re-weighed. The original weight and re-weight must be within ±2.8 mg. If this limit is exceeded, the entire filter lot must be re-weighed

3.4 Post Sampling Filter handling

Filters that are not analyzed immediately should be stored within a protective covering to prevent damage and the loss of particulate matter. A 9 ½" x 11" filter holder card protects the exposed filter and also serves as record of the sample run data. See Section 10 for an example of a filter holder card.

Care should be used when removing the filter from the cassette. Quartz filters are brittle and easily damaged. Once a filter has been removed from the cassette it may be folded length-wise (exposed side in) and placed in the filter holder card. Place any filter pieces that break loose in the card with the filter. This card can now be placed in an envelope for transport to the weighing facility.

3.5 Final Weighing Procedures (Gross Weight)

1. All filters must be equilibrated in a conditioning environment for at least 24 hours as described in Section 3.2.
2. Repeat Steps1 through 4 of the filter tare weighing procedure in Section 3.3.
3. On each day of operation five to seven filters must be re-weighed. Because of the loss of volatile components, no definitive limits are set for exposed filters; however, differences exceeding ±5.0 mg should be investigated.

4.0 Sampler Operation

The procedures in Section 4.0 are guidelines for use in a PM_{10} monitoring program that will accurately reflect trends in local or regional air quality. The effectiveness of the monitoring program depends largely on responsible day-to-day operation of the monitoring site.

4.1 Siting Requirements

Complete siting criteria are presented in 40 CFR Part 50, Appendix L, CFR Part 58, Appendix E and Chapter 1 of this manual. Some general factors to be taken into account are listed below:

- Samplers should be located at a distance greater than 20 meters from trees.
- The distance from a sampler to an obstacle (i.e., building or wall) must be greater than twice the height that the obstacle protrudes above the sampler.
- There must be unrestricted airflow 270° around the sampler inlet.
- There should be no furnace or incineration flues nearby.
- Spacing from roads and traffic may vary.
- The sampler inlet must be at least 2 meters but not greater than 4 meters from a collocated (duplicate) PM_{10} sampler.

Each sampler must be located where the operator can reach it safely despite adverse weather conditions. Operation of the sampler, calibration, and routine maintenance can involve the transportation of supplies and equipment so ease of access must be considered.

Adequate power must be available. Check the manufacturer's instruction manual for minimum amperage and voltage requirements.

4.2 Sampler Installation

1. On receipt of sampler from the manufacturer, inspect to ensure all components are present.
2. Check sampler for proper operation before transport to the field monitoring site.
3. Transport sampler to the site for final assembly and setup.
4. Follow the manufacturer's instructions to assemble the base of the sampler. The shelter must be bolted down to a secure palette or mounting platform.
5. Assemble the sampler inlet according to the manufacturer's instructions and install it on the base unit.
6. Check all power or cord lines for cuts or cracks.
7. Plug the power cord into the line voltage. The use of a ground fault interrupter is highly recommended.
8. Avoid installing power cords or connections where standing water may accumulate.
9. Perform a flow rate calibration as outlined in Section 5.1 and 5.2, Part 2, of this Chapter.

4.3 Sampler Operations

Most PM_{10} samplers are designed to accept filter cassettes. Loading cassettes in the laboratory or designated field office reduces the risk of filter damage and contamination. Filters should be kept in protective folders or boxes prior to being loaded into the sample cassettes. Unexposed filters should never be folded or bent. Filters may be folded after sampling. Each filter should be labeled by the manufacturer with a unique ID number. Each filter should be loaded so that it is centered on the wire screen of the cassette with the numbered side down. Poorly aligned filters show an uneven white border after sampling. Do not over tighten the filter cassette or the filter may stick to the gasket causing filter loss and resulting in an invalid sample. Use a protective cover on the sample cassette before transport to monitoring sites.

Photo 3 PM_{10} Filter Cassettes and Filter Data Card

4.3.1 Sampling Procedures Mass Flow Controlled (MFC) Samplers

Upon arrival at a monitoring site (initial sample setup, no previous sample):

1. Loosen the nuts that secure the inlet to the base and gently tilt the inlet to allow access to the filter support screen. If there is a filter cassette in place, remove it.
2. Examine the support screen on the sampler. Wipe clean if dirty.
3. Remove the protective cover from the filter cassette to be installed and position it in the center of the support screen. Tighten the thumb-nuts sufficiently to hold the cassette securely and to seat the gaskets. Do not over tighten.
4. Secure the inlet to the base.
5. Turn on the sampler and allow the motor to come up to operating speed. Record or confirm the following information on a filter holder/data card:

   - *Site: (*site name*)
   - *AIRS No: (*AQS 9-digit site identification number*)
   - *Flow Controller Serial No.:

- *Hi-Vol Serial No.: (*motor serial number*)
- *Filter No.: (*filter ID number*)
- *Time Start: (*month, day, year, 00:00*)
- Flow Meter Reading: (*initial mass flow controller meter reading*)
- *Initial: (*elapsed timer reading*)
- Setup Operator's initials

* This information may be recorded in the lab or sample preparation area prior to sample setup.

6. Observe the conditions around the monitoring site. Note any conditions that may affect filter particle loading (fire, construction, demolition, etc.).
7. Turn off sampler and ensure that the clock indicates the correct local time and the on/off tabs are set for the next sample period.

As soon as possible after sampling has ended, the operator should return to the monitoring site and recover the exposed filter. Particle loss or filter damage may occur if the filter is left in the sampler for extended periods of time.

1. Record the final elapsed timer reading (Final:).
2. Turn on the sampler and allow the motor to come up to operating speed and record the final flow indicator reading.
3. Turn off sampler.
4. Observe the conditions around the monitoring site. Note any conditions that may affect filter particle loading (fire, construction, demolition, etc.).
5. Raise the sampler inlet and remove the filter cassette. Replace the protective cover.
6. Prepare the sampler for the next run as directed in the previous section.

Photo 4 Sample Pickup/Setup

Photo 5 Install Filter Cassette

4.3.2 Sampling Procedure Volumetric Flow Controlled (VFC) Samplers

Upon arrival at the monitoring site:

1. Loosen the nuts that secure the inlet to the base and gently tilt the inlet to allow access to the filter support screen. If there is a filter in place, remove it.
2. Examine the screen. If it appears dirty or damaged, wipe clean or replace. Remove the protective cover from the clean filter cassette and position it in the center of the support screen. Tighten the thumb-nuts sufficiently to hold the cassette securely and to seat the gaskets. Do not over tighten.
3. Lower the inlet and secure.
4. Turn on the sampler and allow the motor to come to operating speed. Record or confirm the following information on a filter holder/data card:

   - * Initial elapsed timer reading (may be the final reading from the previous sample)
   - * Site Name and AIRS number (AQS site identification number)
   - * Sample Run Date
   - * Filter ID Number
   - * Sampler Serial Number
   - Sample set up date
   - Setup Operator's initials
   - Initial flow indicator reading
   - Ambient pressure (mmHg) and ambient temperature (K)

* This information may be recorded in the lab or sample preparation area prior to sample setup.

5. Inspect and leak check a 36" water manometer and place it to the side of the sampler.
6. Remove the vacuum cap from the stagnation pressure port located on the side of the sampler base. Using the manometer tube, attach one end to the manometer and the other end to the port. Make sure the tubing snugly fits the port and the manometer. Leave the other side of the manometer open to the atmosphere.
7. Measure the initial stagnation pressure (ΔP_{stag})
8. Convert the ΔP_{stag} reading to millimeters of mercury (mmHg) with the equation:
9.

$$\text{mmHg} = 25.4 * \frac{\text{inches } H_2O}{13.6}$$

10. Replace the vacuum cap on the stagnation pressure port.
11. Observe the conditions around the monitoring site. Note any conditions that may affect filter particle loading (fire, construction, demolition etc).
12. Turn off the sampler and ensure that the clock is set for the next sample run date and time.

As soon as possible after the sampling run, the operator should return to the monitoring site and recover the exposed filter. Particle loss or filter damage may occur if the filter is left in the sampler for extended periods.

1. Record the final elapsed timer reading.
2. Turn on the sampler and allow the motor to come to operating speed.
3. Remove the vacuum cap from the stagnation pressure port located on the side of the sampler base. Using the manometer tube, attach one end to the manometer and the other end to the port. Make sure the tubing snugly fits the port and the manometer. Leave the other side of the manometer open to the atmosphere.
4. Measure and record the final ΔP_{stag} on the VFC Sampler Field Data Sheet. This reading must be reported in mmHg.
5. Calculate the average stagnation pressure (ΔP_{stag}) from the initial and final values then record this value on the data sheet.
6. Calculate the average absolute stagnation pressure (P_1) for the sample day and record it on the data sheet where:

$$P_1 = P_{av} - \Delta P_{stag}$$

P_1 = average absolute stagnation pressure, mmHg
P_{av} = average ambient barometric pressure for the run day, mmHg
ΔP_{stag} = average relative stagnation pressure drop, mmHg

7. Calculate and record the average stagnation pressure ratio where:

P_1 = average absolute stagnation pressure, mmHg
P_{av} = average ambient barometric pressure for the run day, mmHg

8. Using the manufacturer-provided table, locate the column and row corresponding to P_1 / P_{av} and the T_{av} value for the sample run day. (T_{av} = average ambient temperature in Kelvin for the run day). Read and record the indicated flow rate.
9. Observe the conditions around the monitoring site. Note any conditions that may affect filter particle loading (fire, construction, demolition, etc.).
10. Raise the sampler inlet and remove the filter cassette. Replace the protective cover.
11. Prepare the sampler for the next run as directed in previous section.

5.0 Calibration Procedures

Calibration is defined as the relationship between an instrument's output and the output of a known reference standard. The sample flow rate must be calibrated and the sampling time (elapsed time meter-ETM) may be calibrated or its accuracy confirmed periodically.

The following equipment is necessary for the calibration of a PM_{10} sampler:

- NIST-traceable certified thermometer (liquid or digital) with a measurement range of 0 to 50 °C with a minimum resolution of 0.1 °C.
- Barometer (digital or aneroid) capable of measuring barometric pressure over the range of 500 to 800 mmHg with a resolution of one millimeter of Hg. The barometer must be within ±5 mmHg of a standard of known accuracy and referenced at least annually.
- Certified orifice transfer standard capable of measuring the flow rate of a high volume PM_{10} sampler. Orifice flow rates are corrected to Standard Reference Conditions.
- Digital, water, or oil manometer with a range of at least 0 to 12 inches and a 0.1 inch resolution.
- Standard time piece of known accuracy within ±2 min/24hr.
- Clean quartz filter as those used for monitoring.

Flow rate determination as described in this section is made using an orifice transfer standard that has been certified according to the procedure presented in Section 2.2.2 of the USEPA's "Quality Assurance Guidance Document 2.11" *and* Chapter 6 "Certification Methods of Transfer Standards" of this manual. See Section 10 of this Part for example certification data that is posted on every certified orifice.

Temperature and barometric pressure units are expressed in Kelvin (°C + 273) and millimeters of mercury (mmHg) respectively. Barometric pressure is always "station" pressure, pressure that is not corrected to sea level. Flow rates are in units of cubic meters per minute (m^3/min) either at standard reference conditions (Q_s @ SRC) or actual conditions (Q_a @ act).

5.1 Mass Flow Controlled (MFC) PM_{10} Calibration.

This MFC calibration procedure assumes the following conditions:

- The PM_{10} sampler is equipped with a mass flow controller to control its sample flow rate.
- The sampler inlet is designed to operate at an actual volumetric flow rate (design flow rate) of 1.13 m^3/min, and the acceptable flow rate range is ±10 percent of this value.
- Calibrations should not be performed on a day that is non-typical for the seasonal weather conditions. If the current season is spring, a calibration should not be performed on a day that is considered extreme conditions for this season (i.e., <5 °C or >25 °C). See Table 1. If a calibration is performed on a day with extreme conditions and an audit or sample run occurs when substantially different conditions exists, the flow rate may be out of the 1.13 m^3/min (@ act) ±10% range (1.02 to 1.24 m^3/min). If the flow rate is outside of this range on the same sample run day, data is invalid.

5.1.1 Calibration Procedure

Note: Do not attempt to calibrate the MFC sampler under windy conditions. Short-term wind velocity fluctuations will produce variable pressure readings by the orifice transfer standard's manometer. The calibration will be less precise because of pressure variations.

1. Measure and record the ambient temperature (T_a) and station pressure (P_a) on the calibration form.

   Place the thermometer out of direct sunlight. Ensure that the thermometer bulb or probe is not in contact with any surface. Allow the temperature reading to stabilize before taking the final reading. If a digital thermometer is used, be sure the unit is in the correct measurement scale (°C) and that it has sufficient battery power (carry extra batteries).

2. If using a liquid manometer, check for leaks prior to placement in-line with the orifice.

   Check for leaks by blowing gently into the manometer tube. If a flow restriction occurs, then the water level will not flow freely. If the two valves at the top of the manometer are not open completely, a flow restriction may occur. A vapor lock can occur if liquid and air get trapped in the two valves. Once the tube is blown into, the water or oil level will elevate on one side and decline on the other. Place a fingertip over the end of the tube when the liquid has risen. If there is a leak, the liquid level will slowly drop. If there are no leaks, the liquid level will not change.

   If a digital manometer is used, be sure the unit is in the correct measure scale (mmHg) and that it has sufficient battery power (carry extra batteries).

3. Check the calibration orifice assembly for leaks.

   The calibration orifice assembly consists of an orifice, faceplate, and filter cassette with one clean filter. A filter is necessary to provide adequate resistance to flow.

   Check the orifice to ensure that it is tightly seated (screwed on) onto the faceplate and that the faceplate gasket is in good condition.

4. Secure the orifice assembly to the sampler. Do not over tighten the nuts as that may result in damage to the faceplate or gasket.

5. Turn on the sampler and allow the motor to come up to operating speed (approximately 3 to 5 minutes).

   Listen for whistling sounds that may indicate a leak in the system. Leaks are usually caused either by a damaged or missing gasket between the orifice transfer standard and the faceplate or by cross-threading of the orifice and the faceplate. Leaks will result in a lower flow rate while torn or improperly aligned filters will result in a higher flow rate.

6. While the sampler is warming up, determine the calibration set-point. The flow rate is adjusted to SRC by using the design flow rate of 1.13 m^3/min @act. Use the following formula to calculate the calibration set point, observed flow @SRC:

$$Q_s = \frac{P_a * 298}{760 * T_a} * 1.13\, m^3 / \min \text{ @ act}$$

Where:

Q_s	=	observed flow rate @SRC
T_a	=	ambient temperature, K
P_a	=	barometric pressure, mmHg

Example calculation:

Where:

T_a	=	20 °C = 293 K
P_a	=	740.0 mmHg

Example calculation:

Where:

T_a	=	20 °C = 293 K
P_a	=	740.0 mmHg

$$\text{Qs (observed)} = 1.13\, m^3 / \min * \frac{740.0 * 298}{760.0 * 293} = 1.13 * 0.99030 = 1.119\, m^3 / \min$$

Once the observed flow @ SRC is determined, the operator must next calculate the required manometer reading for the set point of the flow controller. Use the following formula to calculate inches of H_2O required for the set point:

$$\text{Desired manometer reading, inches } H_2O = \frac{T_a}{P_a} * \text{range factor}$$

Example calculation:

Where:

T_a	=	20 °C = 293 K
P_a	=	740.0 mmHg
Q_s, observed flow @ SRC	=	1.119 m^3/min (round to 1.12)
*average range factor	=	((Low 12.400 + High 12.618)/2) = 12.509

*range factor data from calibration orifice HC18

$$\text{Desired manometer reading} = 12.509 * \frac{293}{740.0} = 12.509 * 0.395946 = 4.953 \quad \textit{round to } 4.95$$

Given the above ambient conditions and the Example Orifice Certification data, the operator must adjust the flow controller (set point) so that the manometer reads 4.95 inches to obtain the flow rate of 1.12 m^3/min @ SRC.

7. Adjust sampler flow controller until the motor is producing a stable flow at the manometer set point as determined above.

   After each flow controller adjustment, allow one to three minutes for the flow to stabilize before making further adjustments. After the final adjustment, turn off the sampler then turn on again to see if the sampler will duplicate the set flow rate. If the operator is unable to achieve a stable flow, the flow controller, motor, or both may need to be replaced.

5.2 Volumetric Flow Controlled (VFC) PM_{10} Calibration

The VFC PM_{10} sampler calibration procedure relates known flow rates (Q_a), as determined by an orifice transfer standard to the ratio of the stagnation pressure to the ambient barometric pressure (P_1/P_a). The stagnation pressure (P_1) is the air pressure inside the sampler in the area just under the filter. VFC samplers have a stagnation pressure tap or port through which the stagnation pressure can be measured.

The VFC sampler's flow control system is a choke-flow venturi. The system must be precisely sized for a given average annual temperature and pressure because no means is provided for the user to adjust the operational flow rate. Therefore, the manufacturer provides a table specific for a given geographic location. VFC PM_{10} sampler calibrations are required annually.

As with the MFC sampler, both the ambient temperature and barometric pressure readings must be determined or estimated during the sampling period for the subsequent calculation of total sampler volume in standard volume units (@ SRC).

Since the volume of air is dependent on the ambient temperature and pressure, VFC PM_{10} units must be calibrated at actual ambient conditions. However, particulate concentration data must be reported at Standard Reference Conditions (@ SRC).

The sampler should not be calibrated under windy conditions since short-term fluctuations will produce variable readings by the orifice transfer standard's manometer. Each orifice is certified @SRC but the following formula may be used to convert orifice readings to actual conditions (@act):

$$Q_a\,(\text{orifice})\,@\text{act} = Q_s\,(\text{orifice})\,@\text{SRC}\,\frac{760 * T_a}{P_a * 298}$$

Q_s (Orifice) @SRC = the flow rate, m^3/min, determined from the orifice certification sheet
T_a = Ambient temperature in Kelvin
P_a = Ambient pressure in mmHg

5.2.1 VFC Calibration Procedure

For this VFC calibration procedure, the following conditions are assumed:

- The sampler uses a choke-flow venturi to control the actual volumetric flow rate.
- The sampler flow rate is measured with the stagnation pressure ratio, and the sampler is not equipped with a continuous flow recorder.
- The sampler inlet is designed to operate at a constant volumetric flow rate of 1.13 m^3/min, and the acceptable flow-rate range is ±10% of this value.

1. Verify that the orifice transfer standard certification is current. Certification information is posted on the side of each orifice.

   A regular orifice requires the use of resistance plates (18, 13, 10, and 7-hole plates) to generate different flow rates. A clean quartz filter is also used for a flow resistance calibration point.

   If a variable orifice is used, then install one clean quartz filter in the sampler and leave it in place throughout the calibration. Load plates are not used. The flow is varied by opening or closing the variable orifice.

2. Calculate and record Q_s (orifice) for each calibration point from the orifice certification table posted on the side of the orifice using the following equations:

$$\text{Orifice Range Factor} = \frac{\Delta H_2O * P_a}{T_a}$$

Orifice Range Factor = data posted on the side of each certified orifice that corresponds to the orifice flow rate @ SRC (Q_s).
ΔH_2O = displacement of water in inches
P_a = ambient pressure in millimeters of mercury (mmHg)
T_a = ambient temperature in Kelvin (K)

Convert this flow to actual conditions using the equation:

$$Q_a \text{ (Orifice @ act)} = Q_s \text{ (Orifice @ SRC)} * \frac{760 * T_a}{P_a * 298}$$

Q_s (Orifice @SRC) = flow rate determined from data posted on the side of each certified orifice
T_a = Ambient temperature, Kelvin (K = °C + 273)
P_a = Ambient pressure, millimeters of mercury (mmHg)

3. Calculate and record the value of the absolute stagnation pressure ratio, P_1, for each calibration point:

$$P_1 = P_a - \Delta P_{stag}$$

Where:

P_1 = absolute stagnation pressure, mmHg
P_a = ambient pressure, mmHg
ΔP_{stag} = relative stagnation pressure, mmHg

4. Repeat this process at four different flow rates. The flow rates can be varied by changing the resistance plates or by adjusting the opening on the variable orifice. At least three flow rates must be within the acceptable flow rate range for the operation of the sampler (i.e., 1.02 to 1.24 m^3/min).

5. On a sheet of graph paper, plot the calculated orifice transfer standard's flow rates, Q_a (orifice), on the x-axis vs. the corresponding stagnation pressure ratios, P_1/P_a, on the y-axis. Draw a smooth curve through the plotted data.

6. If the sampler manufacturer has provided a factory calibration table (i.e., a lookup table) for the sampler, compare Q_a (orifice) for several points on the calibration plot with Q_a (sampler) determined from the factory calibration at T_a. Calculate the percent difference between Q_a (orifice) and Q_a (sampler) using the following formula:

$$\% \text{ Difference} = \frac{Q_a \text{ (sampler)} - Q_a \text{ (orifice)}}{Q_a \text{ (orifice)}} * 100$$

If the % difference is within ±4%, the factory calibration is validated and may be used for subsequent sample periods.

If the difference is greater than ±4%, recheck the accuracy of the orifice transfer standard and recheck the calibration procedure. If necessary, repeat the previous steps, to verify manometer readings, calculations, temperatures, etc. Also check for abnormally low line voltage at the site (should be at least 110 Volts AC), for the correct blower motor and for the presence of a gasket between the motor and the choke-flow venturi.

7. For each calibration point, calculate and record the quantity,

$$\frac{Q_a \text{ (orifice)}}{\sqrt{T_a}}$$

Where:

Q_a (orifice) = actual volumetric flow rate as indicated by the transfer standard orifice, m^3/min

T_a = ambient temperature during sampler calibration, K (K = °C + 273)

8. For the general linear regression model, y = mx + b, let y = P_1/P_a and let $x = Q_a$ (orifice)/$[T_a]^{½}$, such that the model is given by:

$$\frac{P_1}{P_a} = m * \frac{Q_a\ (\text{orifice})}{\sqrt{T_a}} + b$$

Calculate the linear regression slope (m), intercept (b), and correlation coefficient (r). Inspect the plotted calibration curve to determine whether any of the calibration points that are substantially outside of the acceptable flow rate range need to be eliminated so that they do not cause an inappropriate linear regression line.

9. For subsequent sample periods, the sampler's average actual operating flow rate, $\overline{Q_a}$, is calculated from the calibration slope and intercept using the following equation.

$$\overline{Q_a}\ (\text{sampler}) = \{[\ (\ \overline{P_1} / P_{av}\ ) - b\ ] * [T_{av}]^{½}\ * \{1/m\}$$

Where:

$\overline{Q_a}$ (sampler) = the sampler's average actual flow rate, m^3/min

$\overline{P_1}/P_{av}$ = average stagnation pressure ratio for the sampling period

T_{av} = average ambient temperature for the sampling period, K

b = intercept of the sampler calibration relationship

m = slope of the sampler calibration relationship

The average value for P_1 should be calculated from stagnation pressure measurements taken before and after the sampling period. P_{av} should be estimated from barometric pressure for the sampling period.

10. This calibration must be performed:

- annually
- if the results of a performance audit are ≥ ±5.0%
- whenever the flow of any given sample as determined by the stagnation pressure ratio, P_1/P_a, and the manufacturer's look-up table is less than 1.02 or greater than 1.24 m^3/min

6.0 Determining PM_{10} Concentrations

Measurements of PM_{10} mass concentration in the ambient air used to determined attainment status of the National Ambient Air Quality Standards NAAQS must be reported in units of micrograms per standard cubic meter ($\mu g/m^3$) of air. To calculate the concentration of any given PM_{10} sample, the following formula is used:

$$PM_{10} = 10^6 * \frac{(W_g - Wt)}{ET * Qs}$$

Where:

PM_{10}	=	PM_{10} concentration in $\mu g/m^3$
W_g	=	filter weight after sampling (gross weight) in grams
W_t	=	filter weight before sampling (tare weight) in grams
Q_s	=	calibrated flow rate in m^3/min at standard conditions (@ SRC)
ET	=	elapsed time in minutes

The total volume of sampled air is determined from the elapsed time (ET) and the calibrated flow rate of the sampler (Q_s). Since PM_{10} concentration is reported at Standard Reference Conditions (@ SRC), the flow rate and total volume of sampled air are corrected to SRC using the following formula:

$$Q_s = \frac{(P_a * 298)}{(760 * T_a)} * Q_a$$

Where:

Q_s	=	calibrated flow rate in m^3/min at standard conditions
P_a	=	barometric pressure at calibration, mmHg
T_a	=	ambient temperature at calibration, K
Q_a	=	flow rate at actual conditions (@ act)

An example PM_{10} concentration is calculated from the following data:

Q_a (calibration set point)	=	1.13 m^3/min	Initial (tare) filter weight	=	4.290 grams
P_a	=	743 mmHg	Final (gross) weight	=	4.326 grams
T_a	=	277 K	Elapsed Time	=	1427 minutes

$$Q_s = \frac{(P_a * 298)}{(760 * T_a)} * 1.13 = 1.19\ m^3 / \min\ @\ SRC$$

$$PM_{10} = 10^6 * \frac{(4.326 - 4.290)}{1427 * 1.19} = 21.1 \approx 18\ \mu g/m^3$$

To determine sampler flow rate, obtain an average temperature (T_{2av}) and pressure (P_{av}) for individual sample dates. If these average values (or reasonable estimates) cannot be obtained, seasonal average temperature (T_s) and barometric pressure (P_s) in Table 1 may be substituted.

Table 1
Average Seasonal Temperature Chart

Month	Charlestown South Region °F = °C	Indianapolis Central Region °F = °C	Hammond North Region °F = °C
January	31.7 = -0.2	28.7 = -1.9	23.0 = -5.0
February	37.0 = 2.8	33.0 = 0.6	28.3 = -2.0
March	45.0 = 7.2	42.0 = 5.6	36.0 = 2.2
April	48.7 = 9.3	51.7 = 10.9	44.7 = 7.1
May	64.0 = 17.8	62.0 = 16.7	55.0 = 12.8
June	72.3 = 22.4	73.7 = 23.1	67.3 = 19.6
July	76.0 = 24.4	77.3 = 25.2	73.0 = 22.8
August	75.7 = 24.3	77.0 = 25.0	73.0 = 22.8
September	66.7 = 19.3	67.0 = 19.4	64.0 = 17.8
October	56.7 = 13.7	56.3 = 13.5	53.7 = 12.1
November	41.0 = 5.0	38.7 = 3.7	35.7 = 2.0
December	37.0 = 2.8	33.7 = 0.9	29.3 = -1.5

Calculations in this section assume the following:

- Sampler calibrated in actual volumetric flow rate units (act), to a flow of 1.13 m^3/min.
- Individual average temperature and pressure values are used for each site/sampling period.
- All PM_{10} sample results are being reported at SRC.

6.1 Flow Rate Determination Mass Flow Controlled Sampler (MFC)

Use the following formula to calculate MFC PM_{10} sample flow rate where:

$$Q_2 = Q_1 * \frac{P_1}{P_2} * \frac{T_2}{T_1}$$

Q_1 = 1.13 m^3/min (@ act) - set point at calibration
Q_2 = corrected flow to sample day conditions
P_1 = pressure at time of calibration

P_2	=	average ambient pressure on sample day or seasonal average
T_1	=	ambient temperature on day of calibration
T_2	=	ambient temperature on sample day or seasonal average

6.2 Flow Rate Determination or Volumetric Flow Controlled Sampler (VFC)

The average actual flow rate for the sample period is calculated by determining the ratio of the average absolute stagnation pressure to the average ambient barometric pressure and the ambient average temperature (T_{av}) for the sample period.

Use the following formulas to calculate VFC PM_{10} sample flow rate:

1. Calculate the value of P_1 in mmHg where:

$$P_1 = P_{av} - \Delta P_{stag}$$

P_1	=	Average absolute stagnation pressure for the sample period, mmHg
P_{av}	=	Average barometric pressure for the sample period, mmHg
ΔP_{stag}	=	Average initial and final relative stagnation pressure, mmHg

Convert water manometer readings to mmHg using the following formula:

$$\text{mmHg} = 25.4 * \frac{\text{inches } H_2O}{13.6}$$

Use the manufacturer's "look-up" table to determine Q_a from the average stagnation pressure ratio (P_1 / P_{av}) and T_{av} for the sample period. This value of Q_a is the average volumetric flow rate for the sample period.

6.3 Calculation of PM_{10} Concentrations

Accurate reporting of total mass PM_{10} concentrations requires the calculation of the total air volume as explained in Sections 6.1 and 6.2 and the final computation of total mass PM_{10} concentration, Section 6.0.

1. Calculate the volume of air sampled at actual conditions where:

$$V_a = Q_a * t$$

V_a	=	total volume of air sampled in m^3
Q_a	=	average sampler flow rate m^3/min
t	=	total elapsed sampling time in minutes

2. Calculate the total PM_{10} mass concentration in $\mu g/m^3$ where:

$$PM_{10} = 10^6 * \frac{(W_g - W_t)}{V_a}$$

W_g = gross filter weight (after sampling)
W_t = tare filter weight
V_a = total sample volume in m^3/min
= total sample time (min) * sample volume (m^3)

6.4 Data Validation

For each sample run date, determine the 24-hour average barometric pressure and temperature. This data should be site specific and may be obtained for the closest meteorological (MET) monitoring station. Information regarding MET monitoring site locations is available from the IDEM, AMB, Ambient Monitoring Section Chief.

Q_1 = 1.13 m^3/min (or the site calibration set point) corrected to actual condition; using the average pressure and temperature for the sample run date and the following equation:

$$Q_1 = 1.13 * \frac{(P_c)(T_a)}{(P_a)(T_c)}$$

P_c = calibration pressure (mmHg) at calibration conditions
T_c = calibration temperature (K) at calibration conditions
P_a = ambient pressure (mmHg) at run day conditions
T_a = ambient temperature (K) at run day conditions

Using this data, calculate the % difference between the sampler's indicated flow rate (Q_1) and the sampler's design flow rate 1.13 m^3/min where:

$$\text{Design flow rate \% difference} = \frac{Q_1 - 1.13}{1.13} * 100$$

If the design flow rate percentage difference is > 10.0 (1.02-1.24 m^3/min Act), the data for that sample run must be invalidated.

Data must be validated to ensure the PM_{10} measurements are accurate; therefore, seven percent of the total mass concentrations should be recalculated. Gather the following data for the samples to be recalculated:

- total sampling time, min
- average actual volumetric flow rate, m^3/min
- tare and gross weights

Compare the validated PM_{10} concentrations with the original reported values. If a high percent (> 5%) of error is found, recalculate additional samples. If errors are consistent, check all values in the data lot and determine the cause of the error.

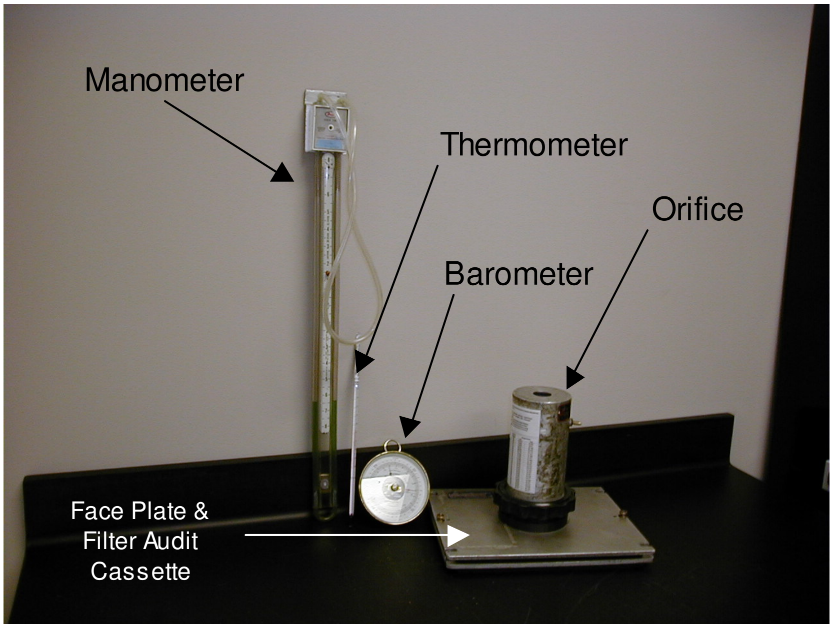

Photo 6 Flow Rate Audit Equipment

7.0 Performance Audit Procedures

The primary goal of an audit program is to identify and to eliminate potential problems that may cause data to be suspect or invalid. Performance audits should be conducted under the following guidelines:

- Perform audit without special preparation or adjustments to the system.
- The auditor must be someone other than the routine operator and have a thorough knowledge of each instrument and process being evaluated.
- Document all aspects of the audit including data on transfer standards, model and serial numbers, calibration information, etc.
- It may be helpful to have the operator in attendance during the audit.

7.1 Flow Rate Performance Audit Procedure for Mass Flow Controlled (MFC) PM_{10} Samplers

For this procedure the following is assumed:

- The MFC sampler uses an electronic mass flow controller for flow rate control.
- The sampler inlet is designed to operate at a flow rate of 1.13 m^3/min at actual conditions with an acceptable range of ±10 percent of this value (i.e., 1.02 to 1.24 m^3/min).

- The audit will not be performed under windy conditions. Windy conditions cause extreme fluctuations in the manometer readings that may result in an incorrect value.
- The orifice transfer standard has been certified by the Indiana Department of Environmental Management's Quality Assurance Laboratory at Standard Reference Conditions (SRC).
- Flow rate audit results are reported to the EPA Precision and Accuracy Reporting System (PARS) @ SRC; therefore, the observed flow rate from the sampler must be converted from actual conditions to SRC.

7.1.1 Equipment

The following equipment is required on site:

- A certified flow rate audit standard (normally a Hansen orifice) and its certification data.
- A water or digital manometer with at least a 0-16 inch range with scale divisions or resolution of 0.1 inch.
- A thermometer capable of measuring ambient air temperatures over the range of 0-50^{o} C to the nearest 1.0 °C. The thermometer should be NIST traceable and or an ASTM thermometer.
- A portable aneroid or digital barometer capable of measuring ambient pressure over the range of 500 to 800 mmHg that has been referenced to within ±5 mmHg to a barometer of known accuracy (annually certified).
- Audit Data Sheet or laptop computer with the OAMD (see Section 10).

7.1.2 Audit Procedure

Avoid auditing on a sampling day to help prevent sample loss or contamination. Since most PM_{10} sites sample on a one in six day frequency, auditing on a non-sample day can usually be accomplished.

1. Measure and record the ambient temperature (T_a) and barometric pressure (P_a) on the audit form.

   Place the thermometer out of direct sunlight. Ensure that the thermometer bulb or probe is not in contact with any surface. Allow the temperature reading to stabilize before taking the final reading. If the temperature reading has not fluctuated in two to four minutes, record the reading.

   If a digital thermometer is used, be sure the unit is in the correct measure scale (°C) and that it has sufficient battery power. Carry extra batteries.

2. Record on the audit form the observed flow @ SRC (calibration set point) from the last calibration.

This data is obtained from the calibration form which may be posted inside the sampler shelter or may be obtained from the OAMD.

The observed flow @ SRC may be calculated if the calibration set point flow @ act temperature and pressure is known. This data is also obtained from the calibration form.

$$Q_s \text{ observed flow @ SRC} = Q_a \text{ calibration set point flow @ act } * \frac{P_a * 298}{760 * T_a}$$

P_a = ambient pressure (mmHg) at calibration conditions
T_a = ambient temperature (K) at calibration conditions

3. Unfasten and carefully tilt-open the sampler inlet head.

4. If present, remove the sample cassette, cover and store it in a location where it will not be damaged.

5. If a liquid manometer is used for the audit, check for leaks prior to placement in-line with the orifice.

   Check for leaks by blowing gently into the manometer tube. If a flow restriction occurs, then the water level will not flow freely. If the two valves at the top of the manometer are not open completely, a flow restriction may occur. A vapor lock can occur if liquid and air get trapped in the two valves. Once the tube is blown into, the water or oil level will elevate on one side and decline on the other. Place a fingertip over the end of the tube when the liquid has risen. If there is a leak, the liquid level will slowly drop. If there are no leaks, the liquid level will not change.

   If a digital manometer is used, be sure the unit is in the correct measure scale (mmHg), adjusted to zero, and that it has sufficient battery power. Carry extra batteries.

6. Check the audit orifice assembly for leaks.

   The orifice assembly consists of an orifice, faceplate, and filter cassette with one clean quartz filter. A filter is necessary to provide adequate resistance to flow.

   Check the orifice to ensure that it is tightly seated (screwed on) onto the faceplate and that the faceplate gasket is in good condition.

7. Install the audit orifice assembly on the sampler.

   Check that the gaskets are in good condition. Tighten the faceplate nuts evenly on alternate corners to seat the gaskets. Do not over tighten. When using an audit filter, do not use resistance plates with the orifice.

8. Turn the sampler on and allow it to warm up (3 to 5 minutes).

9. Ensure that the following is recorded on the audit form:

   - site name, AQS #, audit date
   - flow controller and motor serial numbers
   - audit ambient temperature (T_a) in K (°C = 273)
   - audit barometric pressure (P_a), mmHg
   - calibration observed flow @ SRC (calibration set point)
   - audit orifice transfer standard S/N and calibration information
   - unusual conditions (construction, weather, etc)

10. From the manometer, determine pressure drop across the orifice and record as ΔH_2O on the audit form.

11. Read the indicated flow from the meter in the flow controller electronics box.

12. Calculate the audit flow rate (True Flow @ SRC) through the orifice using the following formula:

$$\text{Orifice Range Factor} = \frac{\Delta H_2O * P_a}{T_a}$$

Where:

T_a = audit temperature, K
P_a = audit barometric pressure, mmHg

True flow rate @ SRC is obtained from the audit orifice certification range factor table. This table is posted on the side of the audit orifice.

Example calculation:

Where:

T_a = 22 °C = 295 K
P_a = 745.0 mmHg
ΔH_2O = 4.8 inches

Example Orifice Certification Range Factor Table (Form 1)

$$\text{Orifice Range Factor} = \frac{4.8 * 745}{295} = 12.122$$

From the Example Orifice Certification Range Factor Table, 12.122 is between the range of low 11.968 and high 12.182. In the table, this corresponds to a true flow @ SRC of 1.10 m^3/min.

If the Certification Range Factor Table is not available, the orifice calibration slope and intercept can also be used to find True Flow @ SRC with the following formula:

$$\text{Qs true flow @ SRC} = \frac{1}{m} * \left[\sqrt{\Delta P * \frac{P_a * 298}{760 * T_b}} \right]$$

Where:

m	=	orifice slope
b	=	orifice intercept
ΔP	=	manometer reading, inches H_2O
P_a	=	audit barometric pressure, mmHg
T	=	audit temperature, K

13. Calculate the % difference between the sampler's True Flow @ SRC (Q_{True}) and the sampler's observed flow rate @ SRC ($Q_{Observed}$ from the last calibration).

$$\%\ \text{difference} = \frac{Q_s\ \text{observed} - Q_s\ \text{true}}{Q_s\ \text{true}} * 100$$

Where:

Q_s true	=	True flow rate @ SRC, m^3/min
Q_s observed	=	Observed flow rate @ SRC (flow set at calibration), m^3/min

Example calculation:

Where:

Q_s true	=	1.10 m^3/min
Q_s observed	=	1.12 m^3/min

$$\%\ \text{difference} = \frac{1.12 - 1.10}{1.10} * 100$$

Audit results (flow rate % difference) produce three possible outcomes or actions:

% Difference	Condition / Data Status	Action
< ±7.0%.	Passed Audit / Data Valid	No action is necessary
> ±5.0% and ≤ ±7.0%	Passed Audit / Data Valid	Calibrate sampler to avoid future data loss
> ±7.0%	Failed Audit / Data Invalid	Calibrate sampler. Data invalid from failed audit until sampler is recalibrated.

7.2 Flow-Rate performance Audit Procedure for Volumetric Flow-Controlled (VFC) HV PM_{10} Samplers

For this procedure, the following is assumed:

- The VFC sampler uses a choked-flow venturi for flow control.
- The sampler's flow rate is measured by a manometer connected to measure the stagnation pressure through a stagnation port.
- The inlet is designed to operate at a flow rate of 1.13 m^3/min at actual conditions. The acceptable fluctuation range is ±10 percent of this value (i.e., 1.02 to 1.24 m^3/min).
- The audit orifice standard is certified by the Indiana Department of Environmental Management, Office of Air Quality, Quality Assurance Section at standard reference conditions (@ SRC).
- Flow rate audit results are reported to the EPA Precision and Accuracy Reporting System (PARS) @ SRC; therefore, the observed flow rate from the sampler must be converted from actual conditions to SRC.

7.2.1 Equipment

The following equipment is required on site:

- An orifice transfer standard (with faceplate) certified by the Indiana Department of Environmental Management, Office of Air Quality, Quality Assurance Section
- An oil or water manometer with a 0-16 inch range and minimum scale divisions of 0.1 inch
- An oil or water manometer with a 0-36 inch range and minimum scale divisions of 0.1 inch or other pressure measurement device for measurement of the sampler stagnation pressure. Ideally, this manometer (or other device) should be associated with the sampler.
- A digital or liquid thermometer capable of accurately measuring ambient air temperature over a range of 0 to 50 °C to the nearest 0.1 °C. This thermometer must be traceable with an accuracy of 0.1 °C to a NIST-certified thermometer or an ASTM thermometer.
- A digital or aneroid barometer capable of accurately measuring ambient barometric pressure over the range of 500 to 800 mmHg to the nearest millimeter Hg and referenced annually to within 5 mmHg to a barometer of known accuracy
- The sampler's calibration relationship (i.e., lookup table or alternative calibration relationship)
- A clean flow-check filter loaded into a filter cassette
- A VFC Sampler Audit Form

7.2.2 Procedure

Avoid auditing on a sampling day to help prevent sample loss or contamination. Since most PM_{10} sites sample on a one in six day frequency, auditing on a non-sample day can usually be accomplished.

1. Measure and record the ambient temperature (T_a) and barometric pressure (P_a) on the audit form.

   Place the thermometer out of direct sunlight. Ensure that the thermometer bulb or probe is not in contact with any surface. Allow the temperature reading to stabilize before taking the final reading. If the temperature reading has not fluctuated in two to four minutes record the reading.

   If a digital thermometer is used, be sure the unit is in the correct measure scale (°C) and that it has sufficient battery power. Carry extra batteries.

2. Unfasten and carefully tilt-open the sampler inlet head.

3. If present, remove the sample cassette, cover, and store it in a location where it will not be damaged.

4. If a liquid manometer is used for the audit, check for leaks prior to placement in-line with the orifice.

   Check for leaks by blowing gently into the manometer tube. If a flow restriction occurs, then the water level will not flow freely. If the two valves at the top of the manometer are not open completely, a flow restriction may occur. A vapor lock can occur if liquid and air get trapped in the two valves. Once the tube is blown into, the water or oil level will elevate on one side and decline on the other. Place a fingertip over the end of the tube when the liquid has risen. If there is a leak, the liquid level will slowly drop. If there are no leaks, the liquid level will not change.

   If a digital manometer is used, be sure the unit is in the correct measure scale (mmHg), adjusted to zero, and that it has sufficient battery power. Carry extra batteries.

5. Check the audit orifice assembly for leaks.

   The orifice assembly consists of an orifice, faceplate, and filter cassette with one clean quartz filter. A filter is necessary to provide adequate resistance to flow.

   Check the orifice to ensure that it is tightly seated (screwed on) onto the faceplate and that the faceplate gasket is in good condition.

6. Install the audit orifice assembly on the sampler.

   Check that the gaskets are in good condition. Tighten the faceplate nuts evenly on alternate corners to seat the gaskets. Do not over tighten. When using an audit filter, do not use resistance plates with the orifice.

7. Turn-on the sampler and allow it to warm up (3 to 5 minutes).

8. Ensure that the following is recorded on the audit form:

   - site name, AQS #, audit date
   - sampler serial number and model
   - auditor's initials
   - audit ambient temperature (T_a) in K (°C + 273)
   - audit barometric pressure (P_a), mmHg
   - audit orifice transfer standard S/N and calibration information
   - unusual conditions (construction, weather, etc)

9. Connect the manometer to the side port on the audit orifice and the sampler manometer to the sampler stagnation pressure port located on the side of the sampler base.

   Ensure that one side of each manometer is open to atmospheric pressure. Be sure that the connecting tubing snugly fits the pressure ports and the manometers. To avoid fluid being drawn into the sampler, do not connect the manometer to the stagnation port prior to turning on the sampler.

10. Read the pressure drop as indicated by the audit orifice manometer (ΔH_2O) and record on the VFC Sampler Audit Form. Read the stagnation pressure drop and record as ΔP_{stag} (mmHg) on the audit form. If the ΔP_{stag} is measured in inches of water, it must be converted to millimeters of Hg with the following equation:

$$\text{mmHg} = 25.4 \ * \ \frac{\text{inches } H_2O}{13.6}$$

11. Turn off the sampler and remove the audit orifice assembly.

12. With only a loaded filter cassette in line, turn on the sampler and allow it to warm up to operating temperature.

13. Read and record the stagnation pressure drop (ΔP_{stag}) for the normal operating flow rate. Turn off the sampler and replace the vacuum cap on the stagnation port.

14. Calculate the audit flow rate (true flow @ SRC) through the orifice using the following formula:

$$\text{Orifice Range Factor} = \frac{\Delta H_2O * P_a}{T_a}$$

Where:

T_a = audit temperature, K
P_a = audit barometric pressure, mmHg
Q_s, true flow @ SRC is obtained from the audit orifice certification range factor table. This table is posted on the side of the audit orifice.

15. Calculate the value of P_1 (mmHg) for the measurements with and without the audit orifice installed.

Where:

$P_1 = P_a - \Delta P_{stag}$
P_1 = stagnation pressure in mmHg
P_a = ambient pressure mmHg
ΔP_{stag} = stagnation pressure drop, mmHg

16. Calculate and record the stagnation pressure ratio for the measurements with and without the audit orifice installed.

$$\text{Stagnation pressure ratio} = \frac{P_1}{P_a}$$

17. Refer to the sampler's look-up table and determine the Q_a (sampler) flow rates (m^3/min) for the measurements with and without the orifice installed as indicated for the ratio of P_1 / P_a and ambient temperature in ^oC. Record these values on the audit form.

Convert Q_a (sampler) to Q_s (sampler) with the following formula:

$$Q_s \text{ sampler observed flow @ SRC} = Q_a \text{ sampler flow @ act } * \frac{P_a * 298}{760 * T_a}$$

18. Calculate the percent difference between the sampler's indicated flow rate @ SRC and the audit transfer standard flow rate @ SRC:

$$\%\text{ difference } = \frac{Q_s \text{ Observed - } Q_s \text{ True}}{Q_s \text{ True}} * 100$$

Where:

Q_s True = True flow rate @ SRC, m^3/min
Q_s Observed = Sampler observed flow rate @ SRC, m^3/min

Audit results (flow rate % difference) produce three possible outcomes and actions:

% Difference	Condition / Data Status	Action
≤ ±7.0%.	Passed Audit / Data Valid	No action is necessary
> ±5.0% and ≤ ±7.0%	Passed Audit / Data Valid	Calibrate sampler to avoid future data loss
> ±7.0%	Failed Audit / Data Invalid	Calibrate sampler. Data invalid from failed audit until sampler is recalibrated.

7.3 Audit Data Reporting

Audit results should be reported to appropriate personnel as soon as possible after audit completion. A paper copy of the audit may be forwarded to the operator or personnel may view the audit in the database. If data is invalid (> ±7.0 percent difference), the auditor should promptly inform the operator verbally and in written form (memo or e-mail).

A standard piece of field equipment for IDEM-OAQ-QAS staff is a cell phone. Immediate notification of results while the auditor is still on-site is now possible. If audit results are ≥ ±7.0% difference, the auditor while at the site should:

- Call the operator with the audit results and request instructions. The operator may ask the auditor not to take any action or to proceed with the next step.

- The auditor may perform a “temporary” calibration of the sampler with the audit device. This calibration will minimize data loss and is in effect until the operator can reach the site to perform any maintenance, equipment replacement, and perform a “permanent” calibration.

If the operator cannot be reached, the IDEM-OAQ-QAS policy is to perform a “temporary” calibration until the operator can perform the “permanent” calibration. A “permanent” calibration by the operator is important so that the independence rule for accuracy audits is maintained (see Section 8.2, Accuracy of this Part).

- Call the operator with the audit results and request instructions. The operator may ask the auditor not to take any action or to proceed with the next step.

- The auditor may perform a “temporary” calibration of the sampler with the audit device. This calibration will minimize data loss and is in effect until the operator can reach the site to perform any maintenance, equipment replacement and perform a “permanent” calibration.

If the operator cannot be reached, the IDEM-OAQ-QAS policy is to perform a “temporary” calibration until the operator can perform the “permanent” calibration.

7.4 Audit Frequency

The U.S. EPA requires that SLAMS monitoring networks audit at least 25 percent of the samplers each quarter thereby auditing each sampler in the network once per year.

The Indiana Department of Environmental Management audits all PM_{10} samplers in its monitoring network at least once each month to ensure minimal data loss due to preventable/foreseeable monitoring problems.

7.5 Systems Audits

System audits are an on-site inspection and review of the total monitoring process from initial filter preparation and sampling to final analysis and data reporting. They are generally done at the initial set-up of a network and on an annual or an as needed basis thereafter. The specific guidelines and procedures for this type of audit can be found in Chapter 15 of this manual, *System Audit Criteria and Procedures for Evaluating Ambient Air Monitoring Networks.*

8.0 Precision and Accuracy Assessment

8.1 Precision

PM_{10} monitoring network precision is estimated by operating two samplers at the same site. Calibration, maintenance, quality control, sampling, and analysis must be conducted in the same manner for each unit. One sampler is designated as the reporting sampler and data from this sampler is used to report air quality. The second sampler is designated as the duplicate or collocated sampler. Data from this sampler is used only for precision calculations. Collocated samplers must be operated simultaneously with the reporting sampler on a minimum of a one in six day sample frequency. Spacing the two samplers between 2 to 4 meters apart ensures that both units are sampling the same air mass but are not interfering with each other's airflow. Precision of the PM_{10} monitoring network is calculated from the percent difference derived from the concentration ($\mu g/m^3$) data pairs over a calendar quarter. These calculations are described in detail in 40 CFR Part 50, Appendix L, CRF Part 50, Appendix A.

The number of collocated sites is based on the size PM_{10} monitoring network of each reporting agency:

- 1 to 5 sites, 1 collocated site
- 6 to 20 sites, 2 collocated sites
- greater than 20 sites, 3 collocated sites

Precision estimations may be improved by installing additional collocated samplers. To further improve the representativeness of the precision data, reporting agencies should select collocated sites that have the highest annual mean concentrations. Also, in reporting organizations that use both Mass Flow Controlled and Volumetric Flow Controlled type samplers, at least one site for each kind of sampling type should be collocated.

8.2 Accuracy

PM_{10} monitoring network accuracy is estimated from the audit of the flow rate of the sampler (Section 7). EPA requires that 25 percent of the samplers within a reporting organization be audited for accuracy each quarter. The audit device and auditor must be different from that of the calibration device and site operator.

The percentage difference between the audit flow rate and the sampler flow rate is used to estimate network accuracy. Calculations are described in detail in 40 CFR Part 50, Appendix L, CRF Part 50, Appendix A.

To improve accuracy estimates, additional accuracy flow rate audits may be conducted each calendar quarter. For example, the IDEM-OAQ-QAS audits all PM_{10} samplers in its monitoring network at least once each month. This audit frequency provides additional accuracy flow rate data and also ensures minimal data loss due to "out-of-calibration" conditions.

Photo 7 Collocated PM_{10} Site – Naval Avionics, Indianapolis

9.0 Maintenance

Routine preventive maintenance is aimed at preventing failure of the monitoring and analytical processes. The overall objective is to increase measurement reliability and prevent data loss. The guidelines below are intended to be general routine maintenance procedures. More detailed information can be found in the manufacturer's instruction manual for individual instruments.

9.1 Sampler Inlets

The Reference Method, 40 CFR Part 50, Appendix L, CRF Part 50, Appendix M has no specific schedule for inlet maintenance. Generally, for both the impaction and cyclonic inlets, follow the manufacturer's recommendation for the dismantling and cleaning of the sampler inlets. Routine cleaning of the inlets will reduce problems with particle bounce. Some samplers may require more frequent cleaning because of the specific field location.

Cyclonic inlets should not be tipped at angles >90° since this may result in leakage of the oil from the middle tube.

9.2 Sampler Bases (MFC and VFC Samplers)

1. Extension cords should be checked routinely for cuts and cracks. Protect (cover) all electrical connections from the elements.

2. Filter screens should be checked at set-up and recovery to ensure that they are clean.

3. Filter gaskets should be inspected during every sample pickup/setup procedure. Worn cassette gaskets may cause the sample to bleed off (under) the gasket. Worn gaskets may also allow leaks that may significantly affect the sampler's flow rate.

4. Motor and housing gaskets should be inspected every 6 months and replaced as necessary.

5. Blower motor brushes wear out and must be changed periodically. Replace brushes according to the manufacturer's instruction, normally every 600 to 1000 hours of operation.

For MFC samplers the flow controller should be replaced if it appears to have:

- no flow
- erratic flow
- excessively high or low flow

Minor adjustments can be made to the flow rate, but most repairs to flow controllers cannot be done in the field. For MFC samplers, the flow controller probe should be cleaned with water or alcohol, prior to routine calibration.

10.0 Forms and Electronic Documentation

Audit, calibration, operation, and maintenance information may be recorded in a variety of ways. Paper forms and "hand" calculations have traditionally been normal method to document this information. However, electronic methods such as spreadsheets and databases are now commonly in use. Section 10 presents paper forms and the database versions used by IDEM-OAQ.

In May of 2000, the Office of Air Quality, Air Monitoring Branch began using a computer database designed to help staff document various field and lab activities. This database, designated as the Office of Air Management Database or OAMD system, is an Oracle-based software program. The OAMD System may be used in the office or it may be transported to the field sites on laptop computers for use in documenting audit and calibration activities.

The system does not directly use or manipulate air quality data such as ozone or sulfur dioxide concentrations. However, the system does provide fast, reliable, and accurate access to calibration, audit, and certification data of the equipment used to collect air quality data (i.e., analyzers and calibration devices).
The system is based on four major activities:

- certification
- calibration
- audit
- verification

Each activity is performed on a variety of environmental parameters such as Sulfur Dioxide (SO_2), Carbon Monoxide (CO), Ozone (O_3), Oxides of Nitrogen (NO- NO_2-NO_X), Particulate Matter (PM_{10} and $PM_{2.5}$). The Certification Activity is performed on the following calibration & audit equipment:

- Gas Blender
- Mass Flow Meter
- "S" Weights
- Anemometer
- Elapsed Time Meter
- Pyranometer
- Hygrometer
- Power Supply
- Temperature
- Ozone Photometer
- Ozone Generator
- A/D Converter
- Barometer
- Psychrometer
- Radiometer
- Multimeter
- Stop Watch
- Thermometer
- Hi-Volume Orifice
- CO Cylinder
- Sulfur Dioxide Cylinder
- Nitric Oxide Cylinder
- Pressure Device, Manometer
- Flow Transfer Standard (FTS)
- Photo Tachometer
- Strip Chart Recorder
- Wind Speed Calibrator

The system uses an inventory of analyzers, calibration devices, and other equipment in conjunction with reference codes and site information to perform and track the above activities. A spreadsheet-type of data entry allows the database user to accurately calculate results related to the above listed activities. Laptop computers are used at air monitoring sites to enter and save field activities such as audit & calibration.

10.1 Certification Activity

Certification is performed on calibration and audit devices (calibrators) in the QA Lab. Certification must be performed before a calibrator can be used for audit or calibration activities. Data obtained from a certification (i.e., slope, intercept, concentration) is used to determine accurate calibrator outputs. The system tracks certification dates and allows the user to determine when equipment is due for re-certification.

10.2 Calibration Activity

Calibration is performed at air monitoring sites so that accurate measurements of pollutants and other environmental parameters are obtained. Calibration is performed in order to adjust a monitoring device's response based on the calibrator's certified output. Calibrations are also performed in the QA Lab on transfer analyzers and are a part of the Certification Activity. The system tracks calibration dates and allows the user to determine when equipment is due for re-calibration.

10.3 Audit Activity

The Audit Activity is performed on analyzers located at air quality monitoring sites. Audits fall into five general categories:

- precision/validation
- precision/validation/accuracy
- validation
- external audit
- non audit

Precision/Validation and Precision/Validation/Accuracy audits may have subcategories depending on the parameter and the type of audit device. For example, the SO_2 parameter has audit subcategories of w/Mass Flow (audit device) and Non Mass Flow (audit device).

10.4 Verification Activity

Verification determines the accuracy of a calibrated QA Lab analyzer and is performed prior to the Certification Activity. The QA Lab analyzer is used during the certification activity to "transfer" a primary standard's accuracy to a secondary or field standard.

Form 1
Example Orifice Certification – Range Factor Table

Indiana Department of Environmental Management
Office of Air Quality – Hi-Volume Orifice Certification

Agency	Cert Date	
STATE QA	10-MAR-2003	
Orifice SN	**Slope**	**Intercept**
HC18	1.9374492	0.0447694

Recertification is Due: 10-SEP-2003

Flow Rates are corrected to Standard Reference Conditions of 298 K and 760 mmHg.

Range Factor = [Manometer Reading * Station Baro Press (mmHg)] / Site Temp (K)

Use the following formulas to directly calculate the true flow:

CM=SQRT[MR*(BP/760) * (298/Temp)]

True Flow = (1/Slope) * (CM – Intercept)

where:

CM = Corrected Manometer Reading

MR = Manometer in inches of water

BP = Barometric Pressure in mmHg

Temp = Ambient Temp in K (C+273)

True Flow (m^3/min)	Range Factor Low	Range Factor High	True Flow (m^3/min)	Range Factor Low	Range Factor High	True Flow (m^3/min)	Range Factor Low	Range Factor High
0.90	8.070	8.245	1.14	12.840	13.062	1.38	18.713	18.981
0.91	8.246	8.424	1.15	13.063	13.286	1.39	18.982	19.251
0.92	8.425	8.605	1.16	13.287	13.513	1.40	19.252	19.524
0.93	8.605	8.787	1.17	13.514	13.741	1.41	19.525	19.798
0.94	8.788	8.971	1.18	13.742	13.972	1.42	19.799	20.074
0.95	8.972	9.158	1.19	13.973	14.204	1.43	20.075	20.353
0.96	9.159	9.346	1.20	14.205	14.438	1.44	20.354	20.633
0.97	9.347	9.536	1.21	14.439	14.674	1.45	20.634	20.915
0.98	9.537	9.728	1.22	14.675	14.912	1.46	20.916	21.199
0.99	9.729	9.922	1.23	14.913	15.152	1.47	21.200	21.485
1.00	9.923	10.118	1.24	15.153	15.394	1.48	21.486	21.773
1.01	10.119	10.316	1.25	15.395	15.638	1.49	21.774	22.062
1.02	10.317	10.516	1.26	15.639	15.883	1.50	22.063	22.354
1.03	10.517	10.717	1.27	15.884	16.131	1.51	22.355	22.647
1.04	10.718	10.921	1.28	16.132	16.380	1.52	22.648	22.943
1.05	10.922	11.126	1.29	16.381	16.632	1.53	22.944	23.240
1.06	11.127	11.334	**1.30**	16.633	16.885	1.54	23.241	23.539
1.07	11.335	11.543	1.31	16.886	17.140	1.55	23.540	23.841
1.08	11.544	11.754	1.32	17.141	17.398	1.56	23.842	24.144
1.09	11.755	11.967	1.33	17.399	17.657	1.57	24.145	24.449
1.10	11.968	12.182	1.34	17.658	17.918	1.58	24.450	24.756
1.11	12.183	12.399	1.35	17.919	18.181	1.59	24.757	25.065
1.12	12.400	12.618	1.36	18.182	18.445	1.60	25.066	25.375
1.13	12.619	12.839	1.37	18.446	18.712	1.61	25.376	25.688

Form 2
PM_{10} / TSP Audit Form

Site: ______________________ **Auditor:** ______________________
Date: ______________________ **Last Audit:** ______________________

Sampler Information

Flow Controller S.N.: ____________ **Flow Controller Calibration Date:** ____________
Motor S.N.: ____________ **Calibration Pressure (mmHg):** ____________
Calibration Temperature (K): ____________

Audit Orifice Information

Orifice S.N.: ____________ **Orifice Certification Date:** ____________

Audit Data

Manometer Reading: ____________ **inches H_2O** **Flow Controller Meter Reading:** ____________

Audit Temp (K): ____________
Audit Press. (mmHg): ____________ **Range Factor** = manometer reading * audit press / audit temp ______

True Flow @ SRC : ____________ **m^3/min** **Calibration Set Flow @ Actual:** ____________

Observed Flow @ SRC: ____________ **m^3/min** **% Difference:** ____________

Comments: ____

$$\text{Observed Flow @SRC} = \text{Calibration Set Flow @Actual} * \frac{P_a * 298}{760 * T_a}$$

Where:

P_a = ambient barometric pressure, mmHg, during calibration
T_a = ambient temperature, K, during calibration

$$\% \text{ Difference} = \frac{\text{Observed Flow Rate @ SRC - True Flow Rate @ SRC}}{\text{True Flow Rate @ SRC}} * 100$$

Form 3
PM_{10} Calibration Form

PM_{10} Calibration Sheet					
Site:				County:	
Date:		Initials:		AQS #:	18-
Ambient Temp.	°C	K (^oC+273)		Ambient Pressure	mmHg

Sampler Information

Orifice SN:		Orifice Cert Date:	
Current Flow Controller SN:		Flow Controller Cal. Date:	
Current Motor #:		Motor Change Date:	
New Motor #:		New Flow Controller SN:	

Formulas

Range Factor (orifice) = ambient pressure * manometer reading in inches H_2O / ambient temperature in K

% Difference = (observed flow – true flow) / true flow * 100

Observed Flow Rate (@ act) = 1.13 m^3/min

Calibration: (Round to 2 decimal places)

$$\text{Observed Flow (@ SRC)} = 1.13 * \frac{\text{(ambient pressure * 298)}}{\text{(760 * ambient temperature in K)}}$$

$$\text{Manometer Reading in inches } H_2O = \frac{\text{(average range factor * ambient temp in K)}}{\text{ambient pressure}}$$

** Find avg. range factor for SRC set point and plug into above formula **

Audit:

$$\text{Range Factor} = \frac{\text{amb press * inches } H_2O}{\text{ambient temp in K}} \quad \text{True Flow (@SRC)} = \text{ from orifice Range Factor table}$$

** When performing an audit, obtain Obs. Flow SRC from previous cal. sheet from the row marked 'C' (indicates the cal. set point). **

Orifice SN	Inches H_2O 1 dec. place	Range Factor H_2O * BP/ Temp (K) 3 dec. places	Obs. Flow (SRC) 2 dec. places	True Flow (SRC) 2 dec. places	% Diff (SRC)	Flow Controller Meter Reading
A						
C						

A = Audit C = calibration

** If an audit could not be performed, please indicate reason in the comments section **

Comments: ______________________________

Form 4
Volumetric Flow Controlled Particulate Sampler Audit Form

Site: ____Date: _____________________________

Auditor: ______________ Sampler Model: ___________________ SN: ____________________

Calibration Date: ______________________ Date of Last Audit: _________________________

Audit Orifice SN: _____________Slope:_______________ Intercept: _______________

Orifice Pressure Drop (ΔH_2O): _____________ Q_s (orifice)[a] @SRC: _____________ m^3/min

(P_a) Ambient Pressure, mmHg: __________ (T_a) Ambient Temperature, °C / K: ____/____

	With Orifice Installed		Without Orifice Installed	
Stagnation Pressure Drop (P_{stag})	______________	mmHg	________________	mmHg
Absolute Stagnation Pressure (P_1)[b]	_____________	mmHg	________________	mmHg
Stagnation Pressure Ratio (P_1 / P_a)	______________		________________	
Q_s (sampler)[c] @SRC	_______________	m^3/min	________________	m^3/min
QA Audit % Difference	_______________	%		

$$^{a}Q_s \text{ (orifice) @ SRC} = \frac{1}{m} * \left[\sqrt{\Delta P * \frac{P_a * 298}{760 * T_a}} - b \right]$$

$$^{b}P_1 = P_a - \Delta P_{stag}$$

$$^{b}Q_s \text{ sampler observed flow @ SRC} = Q_a \text{ sampler flow @ act} * \frac{P_a * 298}{760 * T_a}$$

[c]Determine Q_a (sampler) from manufacturer's lookup table

$$^{d}\text{ \% Difference} = \frac{\text{Qs (sampler) - Qs (orifice)}}{\text{Qs (orifice)}} * 100$$

Comments:

____

____

Form 5
Filter Holder & Data Card (actual size 9 ½ x 11)

Volumetric Flow Controlled PM_{10} Information	PM_{10} / HI-VOL DATA RECORD
	Site: ____
Initial Stagnation Press.: ____	AIRS No.: ____
Initial Barometric Press.: ____	Flow Controller Serial No.: ____
Initial Temperature: ____	Hi-Vol Serial No.: ____
Initial Flow Rate: ____	Filter No.: ____
Final Stagnation Press.: ____	Time Start: ____ 00:00
Final Barometric Press.: ____	mo. day yr.
Final Temperature: ____	Flow Meter Reading: ____
Final Flow Rate: ____	Time Stop: ____ 24:00
Average Flow Rate: ____	mo. day yr.
	Flow Meter Reading: ____
	Pickup Day: ____
	Sample Day: ____
	Final: ____
	Initial: ____
	Elapsed Time: ____
	Average VFC Flow Rate: ____
	This filter was invalidated by: ____ on: ____
	Remarks: ____
	Sample was collected in accordance with the guidelines as set forth in the Indiana Department of Environmental Management, Office of Air Management, Quality Assurance Manual.
	____ Signature